PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H02M 3/335, H05B 6/68	A1	(11) International Publication Number: WO 98/11655 (43) International Publication Date: 19 March 1998 (19.03.98)

(21) International Application Number: PCT/SE97/01520

(22) International Filing Date: 9 September 1997 (09.09.97)

(30) Priority Data:
9603292-5 10 September 1996 (10.09.96) SE

(71) Applicant (*for all designated States except US*): IKL SKELLEFTEÅ AKTIEBOLAG [SE/SE]; P.O. Box 192, S-931 22 Skellefteå (SE).

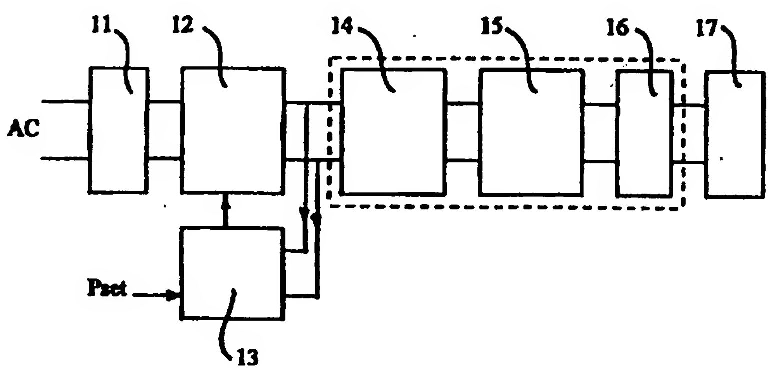
(72) Inventor; and
(75) Inventor/Applicant (*for US only*): LIDSTRÖM, Kjell [SE/SE]; Kritgatan 19, S-930 15 Bureå (SE).

(74) Agent: AWAPATENT AB; P.O. Box 45086, S-104 30 Stockholm (SE).

(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.
In English translation (filed in Swedish).

(54) Title: METHOD AND DEVICE FOR PROVIDING POWER TO A MAGNETRON



(57) Abstract

The present invention relates to a method and a device for providing power to a magnetron from an alternating voltage source. According to the invention, the power supply is accomplished by said alternating voltage being rectified into a rectified voltage which is then converted into a high direct current for powering said magnetron, wherein the power provided to said conversion is controlled based upon a detected actual effect in the power supply means.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

METHOD AND DEVICE FOR PROVIDING POWER TO A MAGNETRON

Technical Field of Invention

The present invention refers to a method and a device for providing power to a magnetron.

Technical Background and Prior Art

Magnetrons are devices which are used in microwave systems for converting electrical energy into microwaves. Magnetrons are for example used as microwave sources in radar equipment, microwave ovens and plasma lamps.

The power supply to a magnetron essentially consists of the voltage which is applied between the anode and cathode (filament) of the magnetron, which is generally called the anode voltage. This anode voltage may be of the order of a few kilovolts. The current passing through the magnetron caused by this voltage is generally called the anode current.

In Fig. 1, there is shown a schematic diagram of a typical relationship between the anode voltage U and the anode current I of the magnetron. Except for extremely small currents, the magnetron shows a relatively low dynamic impedance. This means that very small changes in the anode voltage will give rise to very large changes in the anode current. To compensate for this, the anode current from a power supply unit is preferably provided at a relatively high, preferably inductive, generator impedance.

As the magnetron characteristics or conditions changes, for example because of the magnetron successively being heated and the temperature hence changing during operation, the emission capacity of the filament slowly decaying after use for a longer period of time, the load changing or because of similar circumstances, the voltage to current relationship of Fig. 1 may be shifted in relation to the initial position. Depending on how the power supply is affected or controlled as a result of these changed conditions, the applied anode

voltage and/or the applied anode current may vary considerably.

A known technique for controlling the power supply to the magnetron is based upon the principle that the anode current is controlled under the assumption that the anode voltage is, or is being held, constant.

An example thereof is shown in Fig. 2, wherein a magnetron power supply, comprising a first, rectifying step and a second, high voltage generating step, supplies power to a magnetron, wherein the current is detected just before the magnetron and the high voltage generation is controlled based thereupon.

Much effort has been invested in finding a suitable method for stabilizing the magnetron power, but, due to the complexity of the problem, successes have been limited.

Hence, there exists a need for improved possibilities to control the power supply to a magnetron, especially in applications showing difficult load conditions, such as microwave powered plasma lamps.

Objects of the invention

An object of the invention is to provide a more stable magnetron performance, especially during difficult load conditions.

Another object of the invention is to provide more accurate control of the power supply to a magnetron.

Another object of the invention is to provide a power supply which exhibits very small losses.

Summary of the invention

The above mentioned and other objects are achieved by a method and a device having the features defined in the accompanying claims.

According to an aspect of the invention, power supply to a magnetron from an alternating voltage source is accomplished. The power supply comprises rectifying

the alternating voltage from the alternating voltage source into a rectified voltage which is then converted into a rectified high voltage for powering said magnetron. Furthermore, the power provided to said conversion is controlled based upon an actual power.

The invention is hence based upon the insight as to the advantage of controlling the power in a step preceding the conversion from rectified low voltage to rectified high voltage. Since the power control is performed prior to this conversion, the conversion itself need not comprise power controlling elements, whereby the conversion efficiency is increased considerably.

The inventors have hence come to the insight that the effect of load changes, mains power supply disturbances, temperature and the like, upon the operation of the magnetron can be suppressed by continuously making sure that the power which is provided by an initial power supply stage is constant.

Preferably, the detected actual power is compared to a set desired power and the power provided to said conversion is controlled in order to keep the detected actual power essentially equal to the desired power.

Instead of only using a current value or a voltage value as feedback for controlling the power supply, the inventors have come to the insight that increased control of the magnetron performance is achieved when the power control is based upon a "true" power value.

Furthermore, the inventors have realized the advantage of performing this power control based upon a power detected in association with the initial rectifying and, in any case, prior to the conversion into high voltage.

To avoid having to derive information as to the actual power level from the high voltage generating step or closer to the magnetron, where the high voltage levels make detection of a "true" power value difficult, the power is preferably detected prior to said conversion.

As the power detection as well as the power control based thereupon for keeping the power constant are performed prior to the conversion from rectified low voltage to rectified high voltage, this conversion, as stated, may be designed without the incorporation of controlling or feedback elements, i.e. the conversion may be given an optimal design showing small losses. This means that the power losses in the conversion step will be under good control. By controlling the power prior to an optimized conversion step, there is no need for knowledge about the specific circumstances closer to the magnetron, as these basically follows directly from the controlled power.

According to a preferred embodiment of the present invention, the current provided by said alternating voltage source is also controlled to be sinusoidal, or to have the same wave form as the alternating voltage, and/or to be essentially in phase with the alternating voltage. Thereby, the power supply unit will show a very high power factor, and it is ensured that no harmonics of the mains frequency will be sent back to the public supply network.

It has been found that this current and power control may be integrated into one single unit/function in a very preferable manner. According to yet another embodiment of the invention, the control hence comprises high frequency switching of the rectified signal for providing a controlled, constant and power factor corrected power.

Preferably, an actual current and an actual voltage is detected, together providing said actual power. These actual current and voltage values may then be used for providing power control as well as current control as described above.

According to an especially preferred embodiment of the invention, the measured current and voltage is used in a processing operation, wherein the quotient between the desired power and the mean value of said actual voltage is calculated, resulting in a value of the desired

current mean value. This desired mean value is then multiplied with the quotient between said actual voltage and the mean value of the actual voltage, resulting in the voltage phase factor, to provide an instantaneously desired current value.

Based upon the processing described above, or similar operations which provide a desired current value, the control is performed by comparing the desired current value with the actual current. The current and the voltage is then controlled so as to keep the power constant, and to increase or decrease the current based upon this comparison.

As mentioned above, the invention has the advantage that the conversion step may be designed to exhibit a high efficiency. According to a preferred embodiment, the conversion from rectified low voltage to rectified high voltage is performed by inverting the rectified voltage at a comparatively high frequency, after which the inverted voltage is transformed into an alternating high voltage which is then rectified into said rectified high voltage for powering the magnetron.

As these steps lack monitoring, control, feedback, and the like, incorporated circuits and functions may be tuned in a very preferable manner so that each inverting switching is performed at a zero current crossing and hence essentially without losses. The inversion is advantageously performed by the use of two transistors which are kept active alternately for providing the generally pulse shaped, alternating voltage. As neither the inversion frequency nor the on-off-ratio have to be varied for controlling the power supply, since this control has already been accomplished in a preceding step, the inversion operation performed by the transistors may take place at a 100% duty cycle, thus allowing for said tuning, which in turn allows for the switching at zero current crossings. This is one of the primary factors which contribute to the high efficiency.

Further advantages, aspects and features of the present invention will become more clear from the description below.

Brief Description of the Drawings

Exemplifying embodiments of the invention will now be described with reference to the accompanying drawings, wherein:

Fig. 1 schematically shows a typical relationship between the anode voltage and the anode current of a magnetron;

Fig. 2 shows a block diagram of a power supply unit using control according to prior art;

Fig. 3 schematically shows a block diagram of a power supply unit according to a first embodiment of the present invention;

Fig. 4 schematically shows a block diagram of a power supply unit according to a second embodiment of the present invention;

Fig. 5 schematically shows a block diagram of a power supply unit according to a third embodiment of the present invention;

Fig. 6 schematically shows a block diagram of a power supply unit according to a fourth embodiment of the present invention;

Fig. 7 schematically shoes a detailed exemplifying embodiment of a device according to the present invention;

Fig. 8a to 8e schematically show signal wave forms present in the circuit of Fig. 7;

Fig. 8f schematically shows a simplified diagram of elements included in the circuit of Fig. 7; and

Fig. 8g and 8h schematically show signal wave forms present in the circuit of Fig. 8f.

Detailed description of preferred embodiments

I Fig. 1, there is shown a schematic diagram of a typical relationship between the magnetron anode voltage U and anode current I. Except for extremely small currents, the magnetron shows a comparatively low dynamic impedance.

In Fig. 2, there is schematically shown a block diagram of an example of a prior art magnetron power supply comprising a rectifying stage 1, which rectifies the alternating voltage from an alternating voltage source into a rectified voltage, and a voltage converting step 2, which converts the rectified voltage into a rectified high voltage for providing power to a magnetron 3. In the prior art power supply, the anode current is used as a feedback signal for a control stage incorporated in the voltage converting stage 2.

Fig. 3 schematically shows a block diagram of a power supply unit according to a first embodiment of the present invention. In Fig. 3, a power control step 4, 5 is provided between the rectifying stage 1 and the voltage converting stage 2. The power control step 4, 5 detects the power of the voltage being provided to the converting stage 2, compares this power with a set desired power Pset and continuously controls the power based thereupon. Since there is neither feedback nor control in stage 2, the converting stage may be designed to show an optimized high efficiency, as will be described more fully below.

In Fig. 4, there is shown a block diagram of a power supply unit according to a second embodiment of the invention. The power supply unit in Fig. 4 comprises a first rectifying stage 11, a power control stage 12, a preferably high frequency switching, inverting stage 14, a step-up transformation stage 15, and a second rectifying stage 16, and the magnetron 17 itself. A detecting/-controlling stage 13 detects the power provided to the inverting stage 12 and controls the power control stage

12 so as to keep said power equal to Pset, i.e. so as to keep the power provided to the following stage 14 constant.

As the stages 14, 15, and 16 lack monitoring, control, feedback, and the like, these stages are tuned so that each inverting switching takes place at a zero current crossing and hence essentially without losses. The inversion in stage 14 is achieved by the use of two transistors operating alternately. Since power control has already been accomplished in stage 12, 13, the transistors of stage 14 may operate at a 100% duty cycle. Inductances and capacitances present in the three circuits are dimensioned so as to get a resonance frequency having a ratio, generally equal to 1/1, to the switching frequency in stage 14, thus allowing for said tuning with switching at zero current crosses.

In the embodiment of Fig. 5, the block diagram of Fig. 4 has been supplemented with a power factor controlling stage 18 which makes sure that the current supplied from the AC mains follows the shape of the voltage wave form, which generally is sinusoidal, and that no harmonics are passed to the public power network. With this arrangement, both power control and power factor control are performed in the initial stages without any interference with the tuned stages 14, 15, and 16.

In Fig. 6, there is schematically shown how the power controlling and the power factor controlling functions may be integrated into on single control unit 19. The control unit 19 in Fig. 6 detects the actual power at the output from the rectifying stage, but could just as well detect the power at the input of stage 14, as described in the embodiments above.

A more specific exemplifying embodiment of a magnetron power supply unit according to the invention will now be described with reference to Fig. 7.

The power supply unit in Fig. 7 comprises four functional blocks: a power control block S1, a high

voltage generating block S2, a filament current control block S3 and a processing/control block S4. Furthermore, the power supply unit is arranged to power a magnetron V1. In Fig. 7, the different blocks are schematically separated by dashed lines.

The power control block S1 will now be described in detail.

The power control block S1 of the power supply unit has inputs 10 and 20 connected to an AC voltage power line, which is preferable obtained from the public electricity supply network which provides an alternating voltage of 50 or 60 Hz. The inputs 10 and 20 are connected to a full wave rectifying diode bridge Br1.

The positive output of the diode bridge Br1 is connected to a first output 30 of the block S1 via an inductor L1 provided in series with a diode D1. The negative output of the diode bridge Br1 is connected to a second output 40 of the block S1 via a resistor Rs. A transistor T1 has its collector/drain connected to a point between the inductor L1 and the diode D1 and has its emitter/-source connected to the second output 40 of the block S1. Furthermore, a capacitor C1 is connected between the outputs of the block S1. Together, the inductor L1, the diode D1, the transistor T1, and the capacitor C1 form a high frequency switched power controller.

The on-off-periods of the switch transistor T1 are controlled by a control circuit R which in this example consists of a power factor control circuit, more specifically an integrated circuit of the type UC3854 from Unitrode Integrated Circuits, its incorporation having been modified for obtaining the object of the invention. A more detailed description of the functions of this circuit is to be found in "Unitrode Integrated Circuits Application Note", page 303-310.

The control circuit R comprises a squared signal provider X, a multiplier/divider M/D, a comparator C and a control unit PWC1. A control signal Pset (Power Set)

from the processing/control block S4 is connected to an input A of the multiplier/divider M/D. Furthermore, the positive output of the diode bridge Br1 is connected to an input B of the multiplier/divider M/D and via a low-pass filter LF and the squared signal provider X to an input C of the multiplier/divider M/D. The output of the multiplier/divider M/D is connected to a first input of the comparator C and to the negative output of the diode bridge Br1 via a resistance R1. The second input of the comparator C is connected to the second output of the power control block S1. Furthermore, the output C of the comparator is connected to an input of the control unit PWC1, which output is connected to the gate of the transistor T1.

The function of the power control block S1 will now be described.

According to the invention, the power control block S1 is arranged to ensure that a constant power, the magnitude of which is determined by the signal Pset from the processing/control block S4, is provided to the following blocks/steps independent of variations in the mains voltage or variations in the load or in the inherent characteristics of the magnetron. The power control block S1 also makes sure that the current supply from the mains is sinusoidal and in phase with the voltage.

The incoming mains AC voltage is full-wave rectified in a conventional manner in the diode bridge Br1 so that a pulsating direct voltage V_{in} is obtained between the positive and negative output of the diode bridge Br1. Examples of voltage curves for the network voltage AC and the rectified voltage V_{in} from the diode bridge Br1 are shown in Fig 8a and 8b, respectively.

The current from the rectifying bridge Br1 is then switched at a high frequency by the power controller L1, D1, T1, C1 so that it flows alternately through the transistor T1 and the diode D1. The high frequency switched power controller "chops" the low frequency (typically 50

or 60 Hz) pulsating current at a frequency of the order 100 kHz or higher.

In this specific embodiment, the high frequency switched power controller provides a rectified output voltage which is always larger than the input voltage. In this case, the following block must therefore be designed so that it may always be fed with a voltage which is higher than the highest peak value of the mains voltage.

The operation of the high frequency switched voltage converter will now be described in detail. When the transistor T1 is turned on, the current passing through the inductor L1 will grow, thus making the inductance store energy. When the transistor T1 is turned off, the current through the inductor L1 will charge the capacitor C1 via the diode D1, whereby the current through the inductor decreases. Before the current has reached zero, the transistor is once again turned on, which means that the converter will operates at a continuos current.

The larger the part of the on-off-period of the transistor T1 that the transistor T1 is turned on, i.e. the larger the pulse width of the signal being provided to the gate of the transistor, the lager the difference between the voltage between the outputs of the capacitor C1, i.e. between the outputs of the power control block S1, and the voltage from the diode bridge Br1, i.e. the transistor T1 controls the voltage which is obtained between the outputs 30, 40 of the power control block.

The curves of Fig, 8c, 8d, and 8e show the currents passing through the energy storing inductor L1 at three different pulse width relationships but at the same total time period. In Fig. 8c, the active time is 20% of the total period, in Fig. 8d, the active time is 50% of the total period, and in Fig 8e, the active time is 80% of the total period. The derivative of the increasing current in the curves in Fig 8c to 8e is proportional to the voltage from the rectifying bridge Br1, and the derivative of the decreasing current is proportional to the

difference between the voltage over the capacitor C1 and the voltage from the diode bridge Br1.

The relationship between the time that the transistor T1 is turned on and the time that the transistor T1 is turned off thus controls the power that is provided to the following blocks. According to the embodiment of Fig. 7, this relationship is controlled by the control circuit R.

The interaction between the transistor T1 and the control circuit R thus makes sure that the power provided by the power control block S1 is constant and independent of load or variations in the mains voltage, considering the desired power level set by the signal Pset which is provided by the processing/control block.

The selected power level, which is represented by the control voltage Pset (Power Set), is provided to the input A of the multiplier/divider M/D. The voltage V_{in} from the rectifying bridge Br1 is filtered in the low-pass filter LF, squared in the squared signal provider X and then fed to the input C of the multiplier/divider M/D. The voltage V_{in} is also provided directly to the input B of the multiplier/divider M/D. The voltage from the rectifying bridge Br1 is used as a sample or standard for the wave form of the current. In the equations below, for the sake of simplicity, it is assumed that the network power line voltage is sinusoidal. The mean value V_m of the rectified network voltage V_{in} is obtained from the low-pass filter LF and is fed via the squared signal provider X to the input C. The relationship between the voltage V_{in} and its mean value V_m is given by:

$$V_{in} = \sqrt{2} \cdot V_m \cdot \sin \omega t \qquad (1)$$

The function of the multiplier/divider M/D may schematically be described as follows. By dividing the desired power Pset with the mean value V_m of the actual voltage, a value is obtained corresponding to the mean

value that the current has to show in order to give rise to the desired power Pset. By dividing the instantaneous value of the voltage V_{in} with the value V_m of the actual voltage V_{in}, a factor representing the shape of the voltage wave form is obtained. The desired mean value of the current (which ensures the correct power) multiplied by the wave form of the voltage (which ensures that the current is in phase with the voltage) thus gives a measure of the instantaneous value that the current must have in order to accommodate both these requirements.

Therefore, a factor K is formed in the multiplier/-divider M/D, wherein:

$$K = \frac{A \cdot B}{C} = \frac{P_{set} \cdot V_{in}}{V_m \cdot V_m} = \frac{P_{set}}{V_m} \sqrt{2} \sin \omega t \qquad (2)$$

The output K from the multiplier/divider M/D is hence generated as the currently desired current. This is compared by the comparator C with the actual current Is.

Using the resistance R1, the output signal K is represented as a voltage K × R1, which is provided to one input of the comparator and which has its point of reference at the negative output of the rectifying bridge Br1. Correspondingly, the current Is is represented using the resistance Rs as a voltage Is × Rs, which is provided to the other input of the comparator and which also has its point of reference at the negative output of the rectifying bridge Br1.

The difference between the two voltages K × R1 and Is × Rs, which are provided to the comparator C, forms an "error signal" which the power factor control unit is arranged to eliminate by having the comparator control the transistor T1, as described above, via the pulse width control unit PWC1. As long as K is larger than Is, the transistor is kept turned on, and when Is becomes larger then K, the transistor is turned off. This way, the voltage drop over Rs is brought to be equal to the

voltage drop over R1, i.e. if neglecting the high frequency ripple:

$$s \cdot Rs = K \cdot R1 \qquad (3)$$

which together with the equation (2) gives:

$$s = \frac{R1}{Rs} \cdot K = \frac{R1}{Rs} \cdot \frac{P_{set}}{V_m} \cdot \sqrt{2} \cdot \sin \omega t$$

As is seen, the current Is follows the wave form of V_{in}. Furthermore, the power is obtained as the mean value of the voltage V_{in} multiplied by the current Is:

$$P = \overline{V_{in} \cdot Is} = \frac{R1}{Rs} \cdot P_{set} \cdot 2 \cdot \overline{\sin^2 \omega t} = \frac{R1}{Rs} \cdot P_{set} \qquad (4)$$

which shows that the power is kept equal to Pset except for the factor R1/Rs.

According to the embodiment of Fig. 7, the power control block S1 thus accomplishes several preferable functions: the power from the diode bridge Br1 is controlled to be constant, based upon Pset, and the current Is supplied from the mains is controlled to have the same wave form as the voltage and to be in phase therewith. The power supply unit thereby shows a high power factor. (The power control block S1 further comprises a mains filter (not shown) which makes sure that no high frequency components in the current is submitted to the mains.)

The description of the embodiment in Fig. 7 will now be directed to the high voltage converting block S2.

Generally, the high voltage converting block S2 comprises a high frequency switched half bridge having capacitive voltage division, a transformer and a voltage doubling rectifier. Furthermore, a pulse width control circuit is provided for reasons to be describe below.

More specifically, the block S2 comprises a pulse width control circuit PWC2 having an input, which receives a control signal from the processing/control block S4, and two outputs which are connected to the primary coil of a first transformer Tr1.

Two transistors T2 and T3 are connected in series between the outputs 30 and 40 of the block S1. Furthermore, two capacitors C2 and C3 are connected in series parallel to the transistors T2 and T3. A first secondary coil of the transformer Tr1 is in one of its ends connected to the gate of the transistor T2 and is in its other end connected to the emitter/source of the transistor T2. A second secondary coil of the transformer T2 is in one of its ends connected to the gate of the transistor T3 and is in its other end connected to the emitter/source of the transistor T3.

Furthermore, the high voltage converting block S2 comprises a second transformer Tr2 which has a primary coil having one end connected to a point between the two transistors T1 and T2 and having the other end connected to a point between the two capacitors C2 and C3 via an inductor L2.

The high voltage converting block S2 further has a first 50 and a second 60 output connected to the cathode and anode, respectively, of the magnetron V1. In Fig. 7, the anode is connected to ground. An inductor L3 and two capacitors C4 and C5 are connected in series between the outputs 50 and 60. Furthermore, two diodes D2 and D3 are connected in series parallel to the capacitors C4 and C5. The secondary coil of the transformer Tr2 is in one of its ends connected to a point between the two diodes D2 and D3 and is in its other end connected to a point between the two capacitors C4 and C5.

The block S2 further comprises a third transformer Tr3, having a primary coil in series with the primary coil of the transformer Tr2 and having a secondary coil which in one of its ends is connected to the second

output 40 of the block S1 and in the other end is connected via a diode D4 to an input of the pulse width control circuit PWC2.

The function of the high voltage converting block S2 will now be described.

The output signal from the pulse width control circuit PWC2 controls, via the transformer Tr1, the transistors T2 and T3 to pass current alternately. The switching frequency of the transistors is for example 50 kHz. The choice of frequency depends among other on the power level at which the magnetron is designed to operate.

During normal operation, the high voltage converting block S2 is operated at a 100% duty cycle, i.e. the ratio between the time that any one of the transistors T2, T3 of the high voltage generating block S2 is passing current and the total period is equal to 1. The signal from the pulse width control circuit PWC2 makes each of the transistors T2, T3 pass current 50% of the period time. At start up, before a desired resonance has had time to be established in this "quasi-resonant" converter, the transistors T2 and T3 are activated a shorter time, i.e. at a duty cycle lower than 1. This kind of converter start up is commonly known as slow-start. It is understood that this initial control of the duty cycle of the high voltage converter block S2 is provided but for achieving a soft start of the converter and is hence not intended to be used for continuos control of the power provided to the magnetron during normal operation, as is however the case in prior art.

During normal operation, when the converter S2 operates at a full duty-cycle, half the output voltage from the power control block S1, which is kept at a relatively constant level, is applied with alternating polarity to the primary coil of the transformer Tr2, which up-transforms the voltage considerably, generally to a few kilovolts.

The leakage inductance of the transformer Tr2, in this case supplemented with a separate inductor L2, is approximately tuned to the switching frequency using the capacitors C2 and C3. The transistors T2 and T3 will thus be turned on and off when the current passing through them is very close to zero. The switching losses will hence be very small.

This provides a very advantageous aspect of the invention. Since the converter S2 operates at a 100% duty cycle, this tuning of the oscillation to the switching frequency is made possible, which in turn makes it possible to switch the transistors T2 and T3 when the current is zero.

If the converter were to operate at a lower changing duty cycle, this kind of tuning would not be possible, i.e. switching of the transistors T2 and T3 would not take place at zero crossings and would hence lead to unnecessary switching losses.

The use of a tuned oscillation with a 100% duty cycle consequently results in an increase in the efficiency of the high voltage converting block S2.

The function of the quasi-resonant converter may partly be illustrated by the schematic block diagram in Fig. 8f. In Fig. 8f, the power to the resonance circuit, which schematically comprises an inductor L and a capacitor C, is switched between plus and minus half the supplied voltage E using the transistors Ta and Tb, and the load, which is schematically illustrated by the resistor r, is connected to ground.

In Fig. 8g and 9h, examples of the wave forms of the voltage V and current I in Fig. 8f are shown, said figures clearly illustrating that the current at the time of the switching is very close to zero.

Referring once again to Fig. 7, the serially connected diodes D2 and D3 and capacitors C4 and C5 form a voltage doubling rectifier which puts a lower demand on the ration of the transformer Tr2 and contributes to the

protection against overload at flash-overs in the magnetron, which will be discussed below. The diodes and the capacitors are connected at one arm each of a bridge, wherein the secondary coil of the transformer Tr2 is connected at that diagonal which is formed by the connection points for the two diodes and the two capacitors, respectively, and wherein the output voltage is collected at the other diagonal, where the diodes are connected to the capacitors. The inductor L3 ensures that the magnetron is being provided with an inductive generator impedance, which is generally required for stable operation.

When the magnetron is subjected to very difficult load conditions, flash-overs or short-circuits may occur in the microwave circuits. In order to prevent this from damaging the magnetron or nearby located circuits, the current is monitored using the transformer Tr3 which provides a signal via the diode D4 to the pulse width control circuit PWC2 to temporarily deactivate the switching of the transistors T2 and T3 when a flash-over or a transient occurs in the magnetron. The energy which at that moment may be supplied to the magnetron during a half period is limited to the energy which is stored in the capacitor C3 or C4 since the previous half period, depending on during which half period of the switching that the break is made.

The filament current control block S3 in Fig. 7 comprises a control unit FCC. The control unit FCC conventionally provides a filament current supplied through the cathode of the magnetron V1. The control unit FCC receives its power supply from the power control block S1, but may be designed to use a control function of its own, independent of the operation of the power controller, for controlling the magnitude of the filament current. The operation of the control unit FCC may also be based upon different parameters received from the processing/control block S4.

The processing/control block S4 comprises a microprocessor CPU which provides control and monitoring of the operation of the power supply unit. The microprocessor sends control signals to, and monitors (not shown), the other function blocks. More specifically, the microprocessor is connected to the input A of the multiplier/-divider M/D in the control circuit R for providing the signal Pset thereto, said signal indicating the desired power level. The microprocessor CPU is also connected to the pulse width control circuit PWC2 in the high voltage converting block S2 for controlling the above mentioned slow-start function which is used during slow start or build up of a steady oscillation in the high voltage converting step S2. Furthermore, the microprocessor CPU is connected to the control unit FCC of the filament current control block S3 for providing control signals thereto.

Moreover, the microprocessor may communicate externally using an analogue control voltage (for controlling the power of the magnetron) or using a digital, preferably serial, interface (not shown) which may be bi-directional. According to an embodiment, the interface may use the power supply as a communication link.

Even though the invention has been described with reference to specific exemplifying embodiments, it is understood by those skilled in the art that different modifications, alterations and combinations of the different described embodiments may be made within the scope of the invention, as defined in the accompanying claims.

For example, it is understood that control of the operation of the power supply unit may be realized in many different ways, and hence that the invention is not limited to the embodiment described above.

Although the invention has been described in relation to the supply of power to magnetrons, it is contemplated that certain aspects of the inventions could also be applicable to other types of power supply situations.

CLAIMS

1. Method for providing power to a magnetron from an alternating voltage source, comprising the steps of:

a) converting said alternating voltage into a rectified voltage;

b) converting said rectified voltage, preferably by means of high frequency switching, into a high frequency alternating voltage;

c) transforming said high frequency alternating voltage into a high frequency alternating high voltage; and

d) rectifying said alternating high voltage into a rectified high voltage which is applied to said magnetron for providing power thereto;

wherein said step a) comprises controlling the power provided to the step b) conversion based upon a detected actual power level.

2. Method as claimed in claim 1, wherein said actual power level is detected prior to step b).

3. Method as claimed in claim 1 or 2, wherein said power controlling step comprises:

comparing the detected actual power level with a set desired power level; and

controlling the power provided to the converting step b) in such a way that the detected actual power level is kept essentially equal to the desired power level.

4. Method as claimed in any one of the preceding claims, comprising controlling the current provided from said alternating voltage source to be sinusoidal, or to have the same wave form as the voltage, and/or to be essentially in phase with the voltage.

5. Method as claimed in claim 4, wherein said current controlling step is performed integrated with said power controlling step.

6. Method as claimed in any one of the preceding claims, wherein said controlling step comprises controlling, by means of high frequency switching, the power provided to the step b) conversion.

7. Method as claimed in any one of the preceding claims, wherein said actual power level is detected by detecting an actual current and an actual voltage providing said actual power level.

8. Method as claimed in claim 7, comprising the steps of:

calculating the quotient between said desired power level and the mean value of said actual voltage as a measure of the desired current mean value;

scaling the desired current mean value with the quotient between said actual voltage and the mean value of the actual voltage for providing an instantaneous desired current value; and

relating the desired current value to said actual current and performing said controlling based upon this relation.

9. Method as claimed in any one of the preceding claims, comprising tuning the steps b) to c) so that each inversion switching in step b) is performed at zero current crossings and hence essentially without losses.

10. Method as claimed in any one of the preceding claims, wherein said inversion is performed with 100% duty cycle.

11. Device for providing power to a magnetron from an alternating voltage source, comprising:

first rectifying means (1; 11; Br1) for rectifying said alternating voltage into a rectified voltage;

inverter means (14; T2, T3) for inversion of said rectified voltage into a high frequency alternating voltage;

means (15; Tr2) for transforming said high frequency alternating voltage into a high frequency alternating high voltage; and

second rectifying means (16; D2, D3, C4, C5) for rectifying said alternating high voltage into a rectified high voltage to power said magnetron;

means (5; 13; 19; R) for detecting an actual power; and

means (4; 12; R, L1, T1, C1, D1) for, prior to said inverter means, controlling the power provided to said inverter means based upon the detected actual power.

12. Device as claimed in claim 10, wherein said means for detecting an actual power are provided to detect said power prior to said inverter means.

13. Device as claimed in claim 11 or 12, wherein said control means are provided to compare the detected actual power with a set desired power and to control the power provided to said inverter means in such a way that the detected actual power is kept essentially equal to the desired power.

14. Device as claimed in any one of claims 11 to 13, wherein said control means (18; 19; R) are provided to control the current provided from said alternating voltage source to be sinusoidal, or to have the same wave form as the voltage, and/or to be essentially in phase with the voltage.

15. Device as claimed in claim 14, wherein said control means are provided to perform said current control integrated with said power control.

16. Device as claimed in any one of claims 11 to 15, wherein said control means comprise a high frequency switching converter (T1),

17. Device as claimed in any one of claims 11 to 16, wherein said detecting means are provided to detect an actual current and an actual voltage providing said actual power.

18. Device as claimed in claim 17, wherein said control means comprise processing means (M/D) provided to calculate the quotient between said desired power level and the mean value of said actual voltage as a measure of the instantaneous desired current mean value and to multiply this value with the quotient between said actual voltage and the mean value of the actual voltage to provide an instantaneous desired current value, wherein said control means are provided to relate the desired current value to said actual current and to perform said power control based upon this relation.

19 Device as claimed in claim 18, wherein said control means further comprise comparator means (C) for relating said desired current value to said actual current and to provide a signal which is to be used as a basis for said power control based upon this relation.

20. Device as claimed in any one of claims 11 to 19, comprising means (L2, C2, C3, C4, Tr2) for tuning said inverter means so that each inversion switching is performed at zero current crossings and hence essentially without losses.

21. Device as claimed in any one of claims 11 to 20, wherein said inverter means comprise two transistors (T2, T3) which are alternately active for providing said alternating voltage.

22. Device as claimed in any one of claims 11 to 21, wherein said inverter means (T2, T3) operate at a 100% duty cycle.

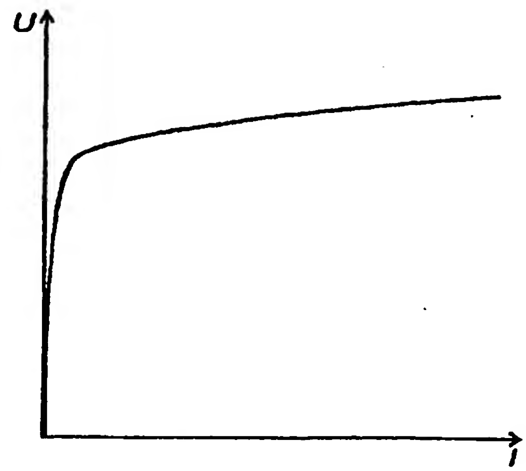


FIG 1

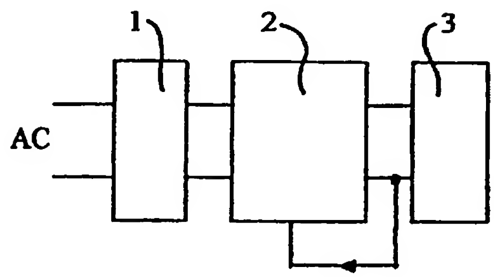


FIG 2

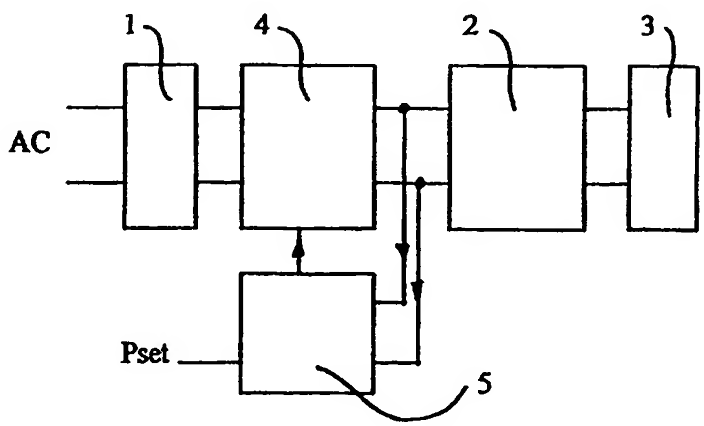


FIG 3

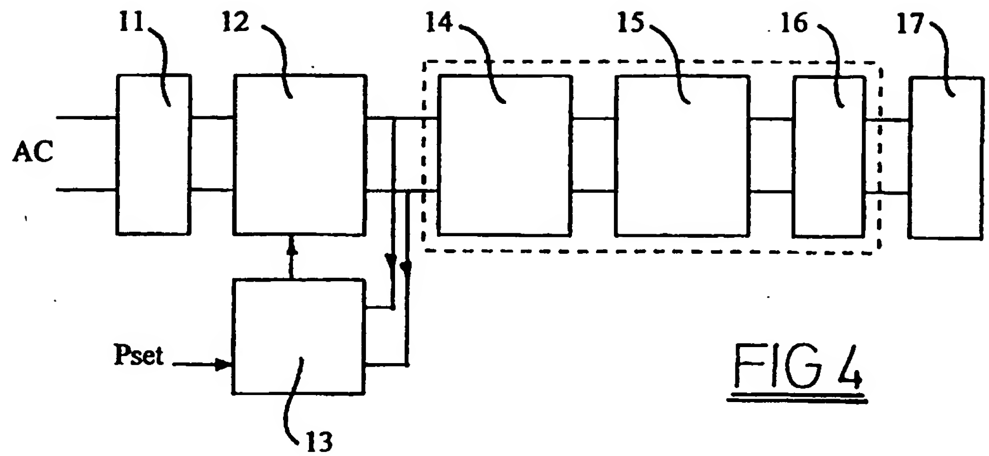


FIG 4

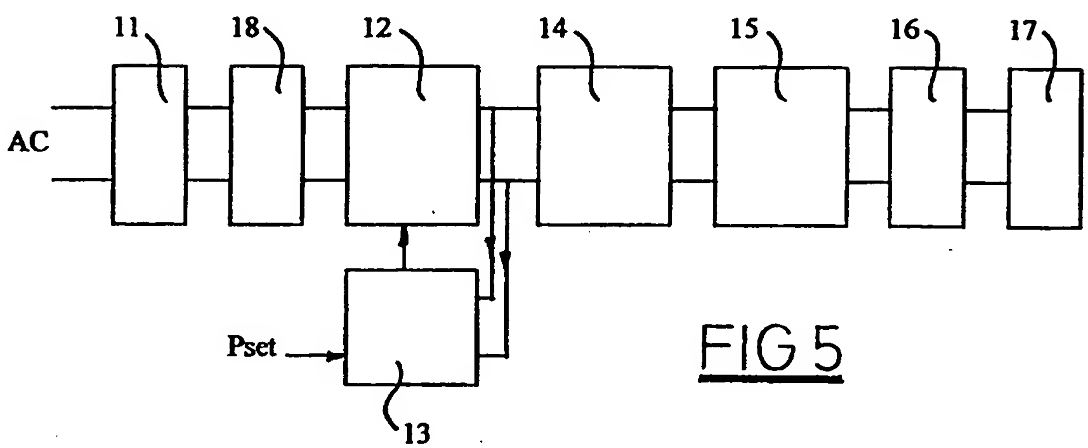


FIG 5

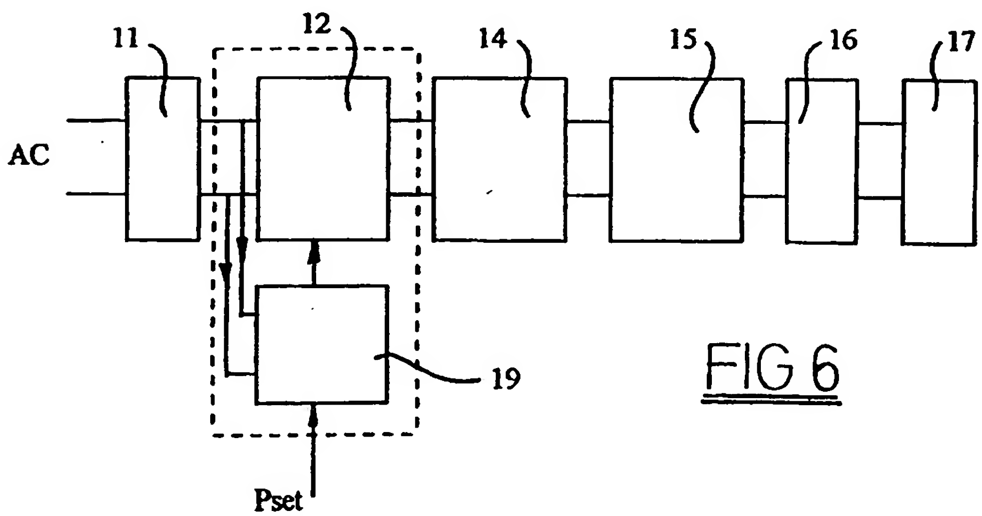
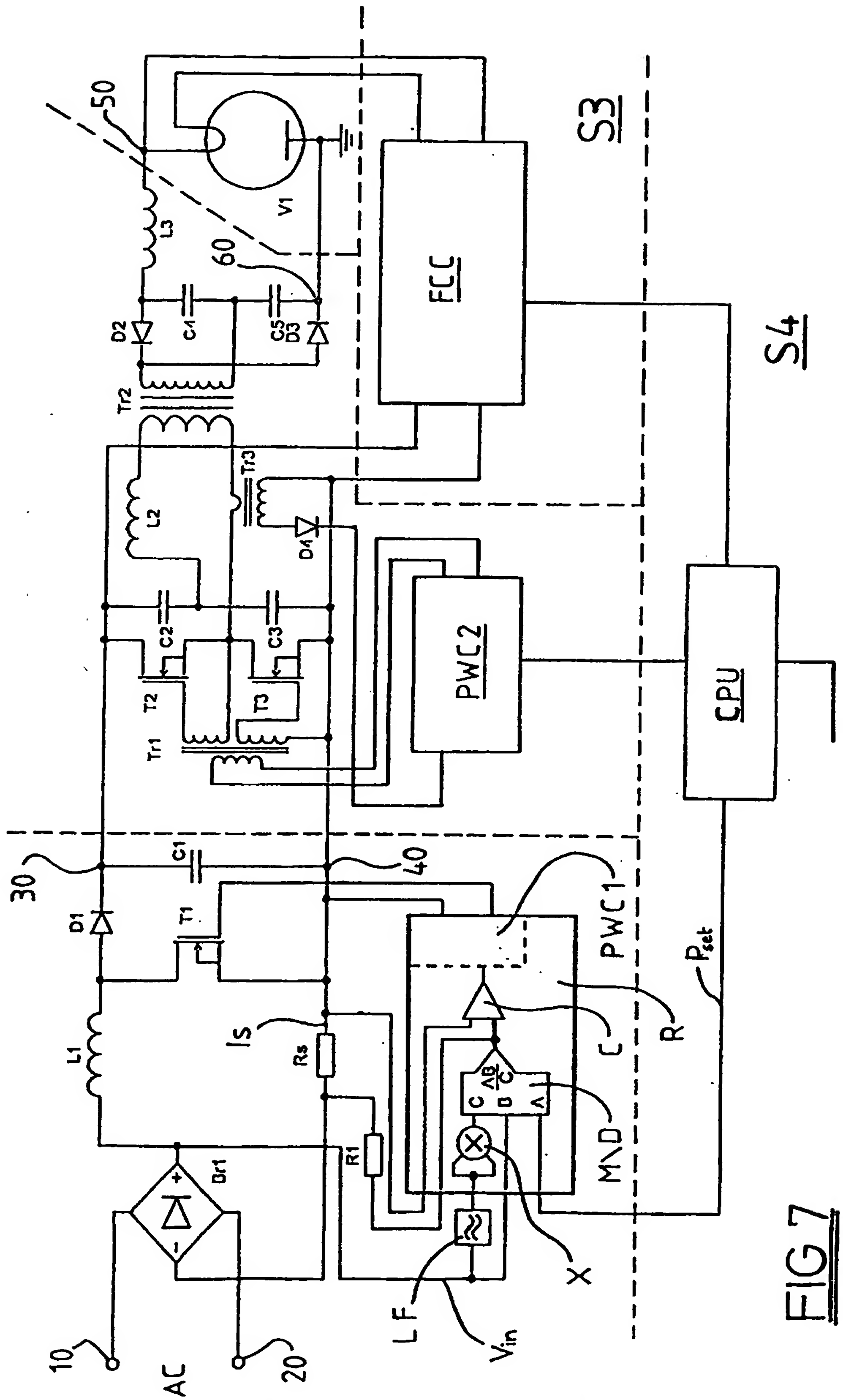


FIG 6



S1
S2
S3
S4
FCC
PWC2
CPU
PWC1
V1
L1
L2
L3
D1
D2
D3
D4
C1
C2
C3
C4
C5
T1
T2
T3
Tr1
Tr2
Tr3
Rs
R1
Is
Br1
AC
10
20
30
40
50
60
LF
V_{in}
X
M\D
C
R
P_{set}

FIG 7

FIG 8a

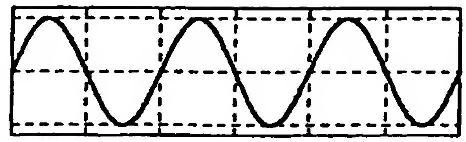


FIG 8b

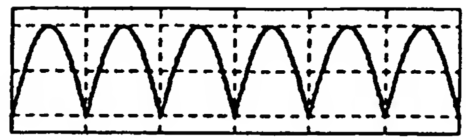


FIG 8c

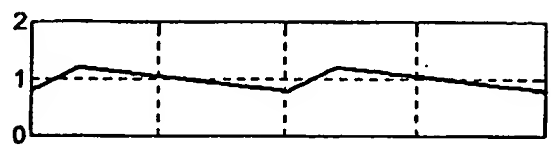


FIG 8d

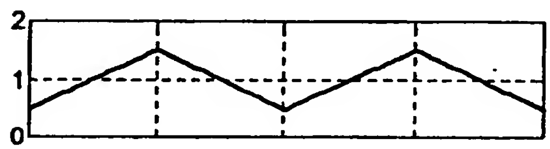


FIG 8e

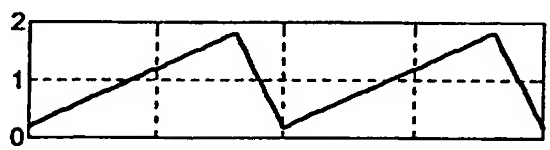


FIG 8f

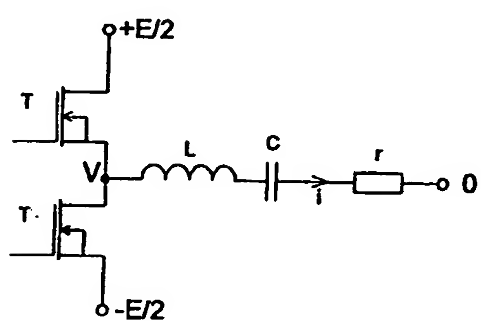


FIG 8g

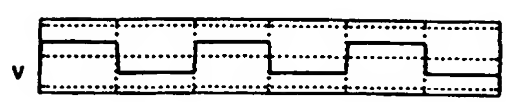


FIG 8h